Faculty Working Papers

AN EXPLORATION OF THE LIMITS OF MODELS FOR EVALUATING ACCOUNTING INFORMATION SYSTEMS

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College of Commerce and Business Administration
University of Illinois at Urbana-Champaign

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April 18, 1977

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Abstract:

Models of decision making based on statistical decision theory have been suggested as a basis for evaluating accounting information systems. This paper uses an inquiry systems (versus decision model) perspective to introduce a four level model for evaluating an information system. The four levels include implementation, formulated problems, world views, and individual meaning systems. Some extensions of previous work with statistical decision theory are introduced to more completely address evaluation needs at the formulated problem level. A method for evaluating informational impacts at the world view level is then developed. At this level of analysis, information is seen to increase as well as decrease the decision maker's internal conflict over the correctness of the formulated problem. This effect does not possess the same properties as uncertainty reduction through state probability revisions at the formulated problem level. Finally some paradoxes in the use of analytical models for evaluating information systems are identified.

This paper is a draft, please do not reference without author's permission. Comments are welcome and will be appreciated.

Introduction

The need for information system evaluation is well established in accounting thought.

> Much, if not most, accounting research is aimed at some facet of the general problem of determining what information should be supplied to a particular decision maker in a particular decision context. Broadly viewed, this is a choice (or decision) situation, and the research in question is concerned with ultimately discovering the "optimum" set of information for the particular decision setting. [9, p. 623]

Using the context of statistical decision theory, models for evaluating alternative information systems have been developed by Feltham [8], Demski [5,6], Feltham and Demski [9], and others [7,13,22,27].

Mock [22] has criticized that work as focusing on a narrow aspect of the total decision making process--the choice of actions in a well formulated problem, with a narrow concept of information--the revision of state probability estimates. He goes on to suggest that learning effects be incorporated into the value of information, and proposes a model value of information (the value of an improved model of the underlying relationships between actions and states of nature) and an action effectiveness value of information (the value of an improved understanding of the effectiveness and efficiency of alternative actions).

Building on that suggestion, this paper views the information system as an inquiring system, and relates the value of information to the process of inquiry. Thus, it attempts to evaluate an information system in a broader perspective. It does not focus on the choice made by a decision maker with a given level of experience in a formulated problem situation, but attempts to build a model of information usage at multiple levels in the inquiry process.

It is a tentative and exploratory study that can, at best, hope to sketch out the domain and difficulties of an expanded approach to information evaluation.

We assume the information system user is engaged in a process of inquiry, or the generation of knowledge useful in action to achieve goals. He acts on the basis of an existing comprehension of his organizational reality, and strives to improve that comprehension. He is engaged in formulating problems as well as in solving them, in inventing solutions as well as in selecting among them, and is actively building an understanding of the world around him to use as a basis for formulating problems and making choices.

We propose a four-level model for evaluating information systems. The four levels extend from interaction in an organization context to the meaning of that interaction for an individual decision maker. Level one is the decision maker's implementation of action choices. Level two is the formulated problem which served as a framework for making the action choice. Level three is the world view (weltanschauung) of the decision maker--the underlying assumptions and beliefs through which he interprets levels one and two. Level four is the meaning of data for the individual--the conjoining of a datum and a world view into a "fact" for the individual.

The model is used as a basis for defining the types of information and learning processes that must be taken into account in evaluating an information system. Statistical decision theory, as currently formulated, is discussed as a partial method for valuing information at the formulated problem level of the proposed model. An extension of statistical decision

theory to allow for act dependent states and uncertain outcomes in the formulated problem is explored, and the need for evaluating information at the world view level of our model is introduced.

In sketching out this expanded analysis of the information evaluation problem, we are quickly confronted with the series of paradoxes in the use of our analytical techniques. All four levels of the model are involved in the process of inquiry by an individual information system user, but each analytical technique addresses only one level of the model. Further, each analytical technique, in order to be tractable, denies the process of inquiry at the next higher level of analysis--yet, in order to be "rational" each technique relies on the "truth" of previous inquiry at the next highest level. Finally, the fourth level of analysis (meaning for the individual) is a question of personal knowledge and can neither be made explicit nor exhaustively enumerated, yet its explicit enumeration is the basis for the "rationality" of any analytical technique of information evaluation.

One suggestion for solving these apparent paradoxes is to shift the attention of information system evaluation away from the information and toward the system. That is, we have traditionally assumed that the value of an information system is to be found in its content, and information analysis has attempted to define the "correct" or "optimum" data for the system to produce. An alternative is to evaluate the information system as a process of inquiry. We then move from asking ourselves "What data gives the 'optimum' answer to a decision maker's question?," to asking ourselves "What is the nature of the decision maker's inquiry process--how is his question being asked?"

Thus, we propose the need to identify classes of problems which must be addressed by a decision maker, and inquiry processes that are available to address those problems. The modes of inquiry displayed by alternative information systems (defined to include the user as part of the system) in relation to the types of problems that must be dealt with, then becomes the basis for evaluating information systems.

The paper is in five sections. We first define our information system user and his organization context. Second, we present our model for information evaluation. In section three, we extend statistical decision theory for act dependent states and uncertain outcomes. Section four introduces meta decision theory and some types of inquiry systems. Section five gives an example of one type of inquiry system (Hegelian) for a traditional accounting problem, draws conclusions, and makes suggestions for further work.

I. The Information System User in Context

A. The User as An Active Inquirer

We begin by making explicit our assumptions about man as an information system user and the organizational context in which he operates.

The model of man as decision maker prevailing in accounting literature today is one of homeostatic self-maintenance. The individual is pictured as passively accepting a problem situation. With a given level of knowlege and experience, he seeks to close gaps between the desired and the actual state of affairs. The problems he is presented with are primarily well structured, with known problem formulations, known solution methods, and a recognized "best" solution.

Our analysis begins with the assumption that man is active in defining the problems he will address rather than passive in accepting problems. He is engaged in a constant process of inquiry to obtain knowledge useful in setting and achieving goals. As a problem solver, the individual is an active sense maker as well as a decision maker. That is, he must build an understanding of his situation, as well as exercise that understanding in an action choice decision.

As Michael Polanyi aptly phrased it:

> There is a purposive tension from which no fully awake animal is free. It consists in a readiness to perceive and to act, or, more generally speaking, to make sense of its own situation, both intellectually and practically. From these routine efforts to retain control of itself and of its surroundings, we can see emerging a process of problem solving, when the effort tends to fall into two stages, a first stage of perplexity, followed by a second stage of doing and perceiving which dispels this perplexity. [25, p. 89]

From the viewpoint of an actively inquiring or sense making user, an information system is not only a source of stimuli to which he responds with choices, but is also a medium through which he builds an understanding (a personal comprehension) of the organizational reality which lies beyond his immediate senses.

This perspective emphasizes his active involvement in shaping his attention to and understanding of the world. An information system user is constantly building and testing a comprehension of his environment that will allow him to interact effectively with it. We are, therefore, interested in evaluating the role of an information system not only for making choices within a given sense of the world, but also its role for making a sense of the world.

An information system user, acting on the basis of a comprehension, inquires (improves his comprehension) by posing questions and problems for himself. Situations which appear to challenge his existing comprehension, or which he anticipates might serve to more fully develop his comprehension, are attended to as problematic. The information system user actively creates and develops problem formulations from these problematic situations which he has identified or found thrust upon him. While decision making may be approached as a discrete activity, inquiry may not. It is a continuous, all-pervasive process. Learning may be a subordinate category of the decision making perspective, but it is a constitutive category of the inquiry perspective.

B. The Context for Inquiry

The information system user is situated in an organizational context. His responsibilities include the setting of goals and objectives, and the defining of mission and policy priorities, as well as planning and controlling for the efficient and effective use of resources in light thereof. He must make a coherent sense of both social and technical processes as they relate to multiple facets of the firm's environment.[1] He searches for opportunities or necessities to act, designs potential action alternatives based on his understanding of the "reasons why", and chooses from among the alternatives.[2]

The problems he confronts range from well-structured, as discussed above, to ill-structured. For the ill-structured problem, a proper formulation is not known, a solution procedure is not known, and a "good" solution cannot be defined in advance of its development.

The organizational functions an information system user must perform include production (basic task accomplishment); maintenance (mediating task and human needs); boundary spanning (obtaining market, social, financial and governmental support for the firm); adaptive (research, planning and coping with change); and managerial (allocating resources, resolving conflicts, coordinating subsystems, and coordinating environmental input and output).[3] The vast majority of these functions result in problems which are ill-structured rather than well-structured.

A difficulty arises as to how statistical decision theory, which assumes well-structured problems, proves useful in evaluating information systems for inherently ill-structured problems.

This difficulty is analogous to one confronted by J. D. Thompson in Organizations in Action [33]. Using a systems perspective, he questioned how classic organization theory which assumed a closed system view and modern organization theory which assumed an open system view could both be persuasively argued. A closed system perspective holds that the number of elements to be taken into account can be exhaustively enumerated, that cause and effect relations between elements can be adequately understood, and that all influences for change can be predicted or controlled. An open system perspective, on the other hand, realizes that the number of elements that are relevant in a given situation cannot be exhaustively enumerated, that cause and effect cannot be explicitly known, and that change comes from influences we neither understand nor control.

He reconciles these two apparently contradicting viewpoints by proposing that organizations (and, we would hold, information system users)

are open systems, but are striving to meet an expectation or norm of rationality. He argues that organizations limit the inputs, outputs and processes they will allow, decouple differentiated components of the organization as semi-isolated units, and maintain buffers between units to further reduce their interaction. In effect, they formulate a solvable problem through decomposition. As a result, the total uncertainty of the situation is reduced, and a relatively closed system, amenable to traditional rational organization theory is created.

We feel this argument also applies to the user of an information system. That is, the user is an open system facing more potentially relevant variables than he can take into account at one time, and facing cause and effect relations and outside sources of change that lie beyond his limited ability to understand. He strives for rationality, however, and artificially closes his problem space to that which can be adequately dealt with by closed system standards of rationality similar to statistical decision theory.[4]

Our model for evaluating information systems focuses not on a particular relatively closed problem formulation, but on the process by which an individual formulates problems, takes action, assesses consequences and reformulates problems as a basis for further action. It recognizes that any given problem formulation is the temporary relative closure of an inherently open question as a basis for taking "rational" action. Information evaluation must attend to this larger process as well as formulated problems if the value of information is to be fully explored.

II. A Multilevel Model for Information Evaluation

We propose a four-level model of the individual information system user. He is implementing decisions in an organizational context (level one), through a framework of attention or a problem formulation (level two) which is developed from the perspective of a world view or his underlying assumptions and beliefs (level three) in order to gain meaning from, and give meaning to, his experience (level four). The basic model is depicted in Figure 1.[5]

The information system user is in the process of interacting with his environment. He is attending to a limited number of elements and relationships in his environment, and interprets the signals he receives through a world view. He makes sense of his situation by identifying the elements and relations to be taken into account (formulating his problem) and taking action in light of what he attends to (solving his problem).

Each higher level of the model becomes successively less available for formalized analysis. First, on the dimension of observability, implementation actions of the information system user are observable, but his problem formulation, world view and personal meaning, are not. Next, while we could argue the ability to exhaustively enumerate his implementation behavior, or his currently formulated problem, we could not claim to exhaustively enumerate his world view or his personal meaning--at the very least because of their symbolic nature.[6] Finally, while we could argue that implementation, problem formulation, and world views could be stated explicitly, the basis of personal meaning remains tacit.[7]

The model is hierarchical to emphasize the following relations between levels:

1) each higher level serves as a basis for selectively retaining or eliminating data at the next lower level,
2) higher levels are revised in light of feedback from lower levels,
3) lower levels experience change and revision at a faster frequency than higher levels, and
4) as a result, higher levels serve as a source of stability, integrity, or rationality for lower levels.[8]

Before discussing the dynamics of the model and some modes of inquiry that relate to it, we will use the model as a framework for identifying three types of information and two types of learning that must be taken into account.

In our model, data is transmitted up, and actions are transmitted down. Actions are here taken to mean the development of world views, the formulation of problems, and the calculation of solutions (or action choices) as depicted in Figure 1. To characterize the types of information which link the four levels of the model we draw on Maruyama [14]. He identifies three levels of information that organize the universe in our thought processes--the classificational level of information, the relational level of information, and the relevantial level of information.

The classificational level of information consists of substances that persist in time and obey the laws of identity and mutual exclusiveness. It is a categorical classification of items as "something". It is noun oriented, discrete and objectively determinable. The categories

in the classification scheme are mutually exclusive through hierarchically formulated as subdivisions in a multi-criteria classification scheme. For our model, information which flows from implementation to the formulated problem is classificational information. It is the information the decision maker attends to.

The relational level of information is event oriented rather than thing oriented. Definition is given by interactions and interrelations as "how does it relate to other things". At this level of information, mutuality of causations and interactions are possible, and subjectivity is as important as objectivity in seeking "truth". This level consists of the potential relationships that may be taken into account by an individual. For our model, information linking the formulated problem level and the world view level is relational information. It is the individual's information as to how things are and how things work.

At the relevantial level of information, definition rests with the unique concerns of the individual, and varies between individuals. The concern is with existential meaning for the individual, and the information may be used for self-centered, other-centered or dominant-submissive reasons. The relevantial level of information is situational and used in immediate action. At this level, using Vickers' terminology [36], the individual merges value judgments with reality judgments in making action judgments. Information which links the world view level to the meaning level is relevantial information. It is the basis for the individual's assertion of self through action in a specific situation.

If the objective is to evaluate an information system as it relates to the implementation of action choices, then all three levels of

information must be evaluated. As we will see in the next section, however, information evaluation in accounting literature has dealt only with the classificational level of information in isolation from the other levels.

We can also use the model as a basis for discriminating at least two types of learning. Here, we will draw on the distinction Argyris [2] makes between single loop and double loop learning. By single loop learning he refers to learning that goes on within a given problem framework. Goals, objectives, values and underlying assumptions of the current problem formulation are not questioned, and learning is in the form of increased efficiency and effectiveness in processes for solving the formulated problem. Double loop learning, by contrast, refers to a questioning and revision of goals, values and implicit assumptions which underlie the problem as it is currently formulated. Double loop learning, in turn, leads to a fundamental rather than cosmetic reformulation of the problem.

For our model, single loop learning takes place at the level of the formulated problem, while double loop learning effects both the world view and the problem formulation. Two points should be made here. First, as before, information evaluation in accounting literature has dealt with only one type of learning--single loop learning, but both types must be evaluated in judging the impact of an information system.

For the problem solving process, we have accepted that man's limited cognitive ability necessitates the framing of problems by elminating all the elements and relations involved in the situation which are not seen as essential. The formulated problem can then always be criticized as incomplete, as indeed it always must be. But it is because the formulated

problem is simplified and incomplete that calculation of a solution is possible. This type of incompleteness of the formulated problem is not an issue in this paper. Calculation of the solution to the explicitly formulated and fully enumerated problem is a trivial exercise. But problem solving does not consist of calculation alone.

Thompson [34], drawing on the work of Duncker and Wertheimer concludes that the problem solving process consists of a series of proposals.

> Each proposal is a re-formulation of the problem. The basis of a new hypothesis is the flexible shifting of all the factors which make up the problem situation in relation to each other. . . The achievement of this re-organization is brought about by varying the mode of attack, changing the basic concept in terms of which the situation is described and interpreted, and changing the principles upon which the hypotheses or "leads" are framed. [pp. 50-53]

Getzels and Czikszentmihalyi [10] in their work on creative problem solving have concluded that it is a result of an individual's problem finding ability. They argue that the ability to reformulate problems is the source of creative problem solutions.

That problem solving requires problem reformulation is not a critical weakness in an information evaluation process that requires a given problem formulation, for we could always reformulate the evaluation framework itself over time. There is evidence to suggest, however, that the process of learning in problem reformulation requires the dynamic interplay of multiple world views. Schroder, Driver and Streufert [30] identify an individuals degree of integrative complexity as the major variable in human problem solving. For our purposes, it is important to note that high integrative

complexity involves the use of multiple world views for interpreting a situation. In fact, not only are multiple world views involved, but the functional relations between the multiple world views used to generate multiple simultaneous interpretations of a situation are explored by a problem solver with high integrative complexity. It appears, then, that while problem reformulation is a key factor in problem solving, information evaluation in accounting assumes a fixed problem formulation, and while effective problem solving and learning by an individual involves the dynamic interplay of multiple world views, statistical decision theory assumes a given world view.

In the next section we will review statistical decision theory as it has been applied to the information evaluation problem in the accounting literature.

III. Information at the Formulated Problem Level

Statistical decision theory (SDT) as used in the accounting literature evaluates an information system at the formulated problem level. This section reviews that evaluation process, identifies some technical limitations in the current SDT paradigm, and explores the removal of some of those limitations. In light of the discussion in sections one and two, some conceptual problems in dealing with information value at the world view level are discussed. These conceptual problems are dealt with in the next section.

A general model of a formulated action-choice (AC) problem (within the SDT framework) can be stated as:

$$\{A, S, \Phi, U, Z \mid \Omega\}$$

where

$A = \{a\}$ is the set of acts available to the decision maker (DM)

$S = \{s\}$ is the set of payoff relevant states of nature

$\Phi = \{\phi\}$ is the set of probability functions

$Z = \{z\}$ is the set of outcomes, normally defined by the act-state pair $\rho(a_i, s_j) = z_{ij}$

U is the value system on Z

Ω is the DM's view of the world based on which the components of the AC problem are specified.[9]

The AC problem is to select an act, $a_i \in A$, such that the DM's expected utility is maximized.[10] In symbols, select the optimal act, a^*, such that

$$EU(a^*) \geq EU(a_i) \text{ for all } a_i \in A \tag{1}$$

where

$$EU(a_i) = \sum_s U(z_{ij})\phi(s_j | a_i)$$ [11]

The value of an information system under this framework (SDT) is defined as the increase in the DM's expected utility due to his ability to take different acts based on the signals generated by the information system. Let $a_\ell^* = a^* | y_\ell, \eta$ such that

$$EU(a_\ell^*) = EU(a^* | y_\ell, \eta)$$

$$= \underset{a \in A}{\text{Max}} \sum_s U(z_{ij})\phi(s_j | a_i, y_\ell, \eta) \tag{2}$$

where y_ℓ is the signal received from the information system η

Then, the expected utility of the DM if he chooses to use the information system η is:

$$EU(a^*|\eta) = \sum_{y} EU(a_\ell^*)\phi(y_\ell|\eta) \tag{3}$$

$$= \sum_{y} [\underset{a \varepsilon A}{\text{Max}} \sum_{s} U(z_{ij})\phi(s_j|a_i,y_\ell,\eta)]\phi(y_\ell|\eta)$$

and the expected value of the information system η is:

$$V(\eta) = EU(a^*|\eta) - EU(a^*) \tag{4}$$

[12]

Then the information systems choice problem is to select the system η^* such that:

$$V(\eta^*) \geq V(\eta_k) \quad \text{for all } \eta \varepsilon \mathcal{H} \tag{5}$$

If an information system can predict the occurrence of the payoff relevant states with certainty, we call the information system "perfect". The value of a perfect information system (η_p) can be calculated as:

$$V(\eta_p) = \sum_{y} U(z_*)\phi(y_\ell|\eta_p) - EU(a^*) \tag{6}$$

where z_* is the outcome of the act state pair (a_ℓ^*, s_ℓ),

and s_ℓ is the state predicted by the signal y_ℓ.[13]

The $V(\eta_p)$ is the maximum value of any information system for the formulated AC problem. The measure can also be interpreted as the (opportunity) cost of uncertainty in the formulated problem. That is, the decision maker "lost the opportunity" to enjoy the utility of optimal acts due to uncertainty of the states of nature.

We can now relax an assumption stated in the standard SDT formulation: certain outcome prediction. Up to this point, we have assumed a homomorphic mapping of the act-state pair into the outcome space (i.e., $\rho(a_i,s_j) = z_{ij}$). In an actual decision situation, this assumption is not likely to hold true (e.g., profit for a given amount of sales). Thus, we let the (a_i,s_j) pair map into the outcome space Z with corresponding probabilities for the elements of Z: $\rho(a_i,s_j) \rightarrow Z \sim \phi(z_k|a_i,s_j)$.

Then the expected utility measures need to be adjusted as given below:

$$EU(a_i) = \sum_s [\sum_z U(z_k)\phi(z_k|a_i,s_j)]\phi(s_j|a_i)$$

$$EU(a^*) = \underset{a\epsilon A}{\text{Max}} \sum_s [\sum_z U(z_k)\phi(z_k|a_i,s_j)]\phi(s_j|a_i)$$

$$EU(a_\ell^*) = EU(a^*|y_\ell,\eta)$$

$$= \underset{a\epsilon A}{\text{Max}} \sum_s [\sum_z U(z_k)\phi(z_k|a_i,s_j,y_\ell,\eta)]\phi(s_j|a_i,y_\ell,\eta)$$

$$EU(a^*|\eta) = \sum_y EU(a_\ell^*)\phi(y_\ell|\eta)$$

$$= \sum_y \{\underset{a\epsilon A}{\text{Max}} \sum_s [\sum_z U(z_k)\phi(z_k|a_i,s_j,y_\ell,\eta)]\cdot$$

$$\phi(s_j|a_i,y_\ell,\eta)\}\phi(y_\ell|\eta)$$

$$V(\eta) = EU(a^*|\eta) - EU(a^*) \qquad (7)$$

Equation (7) is more comprehensive than the standard SDT formulation since it incorporates uncertain outcomes as well as act dependent states of nature. Consequently, the problem specification requirements are more extensive. The additional specification requirements include the

prior probabilities and the rules to revise them after the receipt of information. Under the standard form the necessary probability distributions are: $\phi(s_i)$, $\phi(y_\ell|\eta)$ and $\phi(y_\ell|s_i,\eta)$ and all the necessary probability revisions are performed according to Bayes' rule.[14]

Under the expanded formulation given above, the specification requirements are far more extensive and the probability revision rules are more complex. Specifically,

(1) The state probability function needs to be specified for each act. In fact, the marginal probability of the states of nature is meaningless under this formulation, since one and only one act is to be selected. Thus we need to specify $\phi(s|a)$ for each $a\epsilon A$.

(2) The uncertain outcome assumption requires the DM to specify the probability measures $\phi(z|a,s)$ for each (a,s) pair in A,S.

(3) The interpretation of the term $\phi(y|\eta)$, can be quite complex. If the information system were to report the observations of past events, the condition probability could be stated as:

$$\phi(y|\eta) = \sum_{\bar{s}} \phi(y|\bar{s},\eta)\phi(\bar{s})$$

where the $\bar{S}$ is the set of past states.

Note, however, the $\phi(\bar{s})$ is conditional on the past act selected $\bar{a}$. Therefore the entire expression $\phi(y|\eta)$ is conditional upon $\bar{a}$.[15]

If the information system were to report the values of an experiment yet to be performed, then selection of the act (or acts) to be used in the experiment, a_e, becomes another choice problem

and the $\phi(y|\eta)$ is again conditional upon the act selected. The impact of this dependence on the act selected ($\bar{a}$ or a_e) upon the probability revision process is discussed next.

(4) The condition probability $\phi(s|a,y,\eta)$ needs to be elaborated upon. Let us digress a moment and intuitively consider the role of information in revising the act dependent state probabilities. The prior state probability $\phi(s|a)$ reflects two major components: (a) the perceived action effectiveness in inducing the state [22], and (b) the general likelihood of the state occurrence. The DM may find a signal to be informative with regard to the action effectiveness and/or the general likelihood of the state occurrence. Therefore, the revision process of the state probabilities must be able to reflect the potential impacts of information on both components.[16]

Now let us consider the calculation process of $\phi(s|a,y,\eta)$. Without loss of generality, let us assume the information system reports on the past state occurrence $(\bar{s},\bar{a})$ as described in (3) above. The probability revision can be calculated as follows.

$$\phi(s|a,y,\eta) = \sum_{\bar{s}} \phi(s|\bar{s},\bar{a},a)\phi(\bar{s}|y,\eta)$$

$$= \sum_{\bar{s}} \phi[(s|a)|(\bar{s},\bar{a})] \frac{\phi(y|\bar{s},\bar{a},\eta)\phi(\bar{s}|\bar{a})}{\sum_{\bar{s}} \phi(y|\bar{s},\bar{a},\eta)\phi(\bar{s}|\bar{a})} \tag{8}$$

where $\bar{s}$ is the past state observed by the information system η and $\bar{a}$ is the act taken in the last period.

The second component $\phi(\overline{s}|y,\eta)$ refers to the accuracy of the observation system η while the first component $\phi[(s|a)|(\overline{s},\overline{a})]$ refers to the informational impact of the past act taken, $\overline{a}$, and the state resulted, $\overline{s}$, upon the evaluation of the future state probabilities. Schoner [29] has suggested a means to calculate the revised probability $\phi[(s|a)|(\overline{s},\overline{a})]$. One crucial requirement is that the DM specify the probabilities of one state (s_j) obtaining under one act, (a_i), conditional upon the knowledge of states $(s_j$ or $s_\ell)$ obtaining under one or more other acts, (a_k), $\phi[(s_j|a_i)|(s_\ell,a_k)]$, which he calls <u>cross-prior probabilities</u>.

(5) The uncertain outcome formulation requires prior probabilities on $\phi(z|a,s)$ for the Cartesian product of AxS. The impact of information is reflected in the revised probabilities $\phi[(z|a,s)|y,\eta]$.[17] The revision process is quite similar to the state probability revision discussed above, except that the information system observes the outcome $(\overline{z}|\overline{s},\overline{a})$ along with the $(\overline{s}|\overline{a})$. The information signal then could be thought of as the pair $[\eta(\overline{z}|\overline{s},\overline{a}),\eta(\overline{s}|\overline{a})]$.

Some Reflections

Two points emerge from the above discussion: (1) an expanded view of information system evaluation, and (2) some technical limitations of SDT as a model for evaluating information systems.

(a) Under the expanded formulation incorporating uncertain outcomes and act dependent states of nature, the potential value of information is divided into three components:

(1) the outcome mapping of the act state pairs, (2) the action effectiveness evaluation, and (3) the general likelihood of the state occurrence. These components were suggested earlier by Mock [22], and are formalized in this paper.

(b) To make this model operational, procedures for revising the probabilities, $\phi[(s|a)|y,\eta]$ and $\phi[(z|a,s)|y,\eta]$ are necessary. Unfortunately, standard Bayes' rule does not provide the means for these revisions. In fact, only the act independent and certain outcome cases can be handled by Bayes' Theorem and consequently only the state likelihood component of information can be evaluated under the standard SDT. This problem is a technical one (vs. conceptual) since its solution, once developed, can fit into the basic framework of SDT.

Once the DM specifies all the components listed above, he has a formulated problem. If, however, we admit a question as to what criteria to use in making those judgments, we have a meta theory decision problem. This problem is at the world view level, and is a conceptual rather than a technical problem. It is conceptual in that it lies beyond the standard SDT framework. Information analysis at the formulated problem level, as developed above, took place within a given world view (Ω_0), information value was in single loop learning, and only categorical level information was considered. Since SDT assumed agreement on the assumptions behind the formulated problem, we cannot use it to question those assumptions.[18] Type I and Type II errors can be discussed at the formulated problem level only because agreement on the world view is assumed. To question the world view we need to introduce the possibility of a Type III error

(having formulated the wrong problem). In order to address this question, and the role of information in its resolution, we must appeal to a theory that lies beyond SDT--a meta theory for SDT that evaluates information at the world view level.

IV. Information at the World View Level

The meta theory decision problem is "to discover a procedure for formulating one's decision theory problem [19, p. 44]." At the formulated problem level of our decision model, the DM's view-of-the-world, Ω_0 was assumed as given. The object of inquiry in this section is the implication of the conditioning elements Ω on the formulated problem, and the impact of information on the DM's view-of-the-world. Up to this point, the analysis assumed that the receipt of information did not cause the DM to question the validity of the formulated AC problem. We now expand the concept of learning to a higher-order of problem formulation (double loop learning), and evaluate relational level information. The analyses of Ω and the informational effects on Ω cannot be stated within the statistical decision theory paradigm, as pointed up by Mitroff and Betz [19, p.44].

> Criteria for making judgments required in applying the logical form in any particular instance are outside the form itself and are hence extra-logical (or meta-logical as the term is generally used). A meta theory is another logical form (or a higher-order logical form) for formulating the decision to formulate a decision problem.

The analysis reported here is at best preliminary and mainly consists of assertions and hypotheses, which we hope can serve as a basis for further research. We believe, however, that the impact of learning on a DM's view-of-the-world and the role of information in the learning process is

quite important in evaluating potential information systems, and warrants substantive research.

Churchman considers the passive nature of most information systems to be their major weakness, as summarized by Mitroff: "In short, most systems do not inspect the user's underlying images of the world. As a result, they are unable to examine how all the user's unstated and unconscious assumptions profoundly affect the user's conception of his own problem." [18, p. 634]

One type of meta theoretic approach to the application of SDT at the formulated problem level is an inquiry systems framework first developed by C. W. Churchman [3], and further elaborated by Mitroff and Betz [19], Mitroff and Pondy [21], and Mitroff, Betz and Mason [20]. It is a meta theory in the sense that it does not address the solution to a formulated problem, but the process by which implementation, formulated problems, world views and meaning systems interact as an inquirying system. Types of inquiry systems differ as to their use of sense data, consistent theory, multiple theories, and implementation as a basis for establishing "truth".[19]

Hegelian or dialectical inquiring systems have been used by some authors to explore changes in the DM's world views [15,18,19,20]. For an Hegelian dialectical inquirer, disagreement, not agreement, is the method of conducting inquiry. Thus, learning takes place through debates between strongly conflicting views on an issue. A dialectical inquiring system has two expert debaters with opposing views debating for the benefit of the decision maker. The DM then forms his own view by adopting

or transforming the views expressed by the experts and incorporating them into his previous view. We wish to evaluate the information system based on its ability to take on the role of debaters, or alternatively, its ability to induce the DM to consider other views. We start the analysis with a discussion of the role and structure of a world view.

A. Ω - Weltanschauung

The Weltanschauung (view-of-the-world or world view) is the DM's understanding of the logical relationship among variables. That is, as the DM receives a datum y_i, describing a past, present, or future event, he decodes the symbol y_i into an information bit through his world view. Specifically,[20] let Y be a set of "data" initially possessed by the DM, $Y = \{y_1, y_2, \ldots, y_k\}$, let Ω be a set of models (world views) $\Omega = \{w_1, w_2, \ldots, w_\ell\}$, and let x be an operator conjoining an element of the set Y with an elements of the set Ω, such that for every $y_i \varepsilon Y$ and every $w_j \varepsilon \Omega$, there exists one and only one element of a set F: $y_i x w_j \rightarrow f_{ij}$. The operator x is called the interpretative operator and the set F, which we call the information set of a given Ω, contains the "facts" as the DM understand the y_i within the context of a given decision problem. Thus, a "fact" cannot be separated from the DM's current view-of-the-world. Then, the AC problem specification is based on the facts in $Y_0 \times \Omega_0 \rightarrow F_0$, where the subscript 0 indicates the present. That is, all the components of the AC problem are specified based on the facts as they are known to the DM at the time of problem formulation. We wish to evaluate the potential impact of new data $y_j \notin Y_0$ upon the world view Ω_0, and thus on the "facts" F_0.

Let us modify the structure of the world view somewhat and introduce uncertainty as to the validity of some competing views. The DM does not possess one world view, but a set of views with credence attached to each view in the set.[21]

Let $\Omega_0 = \{C_1 w_1, C_2 w_2, \ldots C_\ell w_\ell\} = C'w$

where w_i is a unique view in the set

c_i is the credence attached to w_i

$c_i \geq 0$, and $\Sigma C_i = 1$

In addition to the impact of information reflected in the AC problem formulation, the receipt of a datum may change the DM's world view and/or change the "fact" known to the DM before the receipt of the datum. That is, a datum may impact both the categorical and the relational levels of information for the DM. Consider $y_i \varepsilon Y$, $\Omega_0 \times y_i \rightarrow f$, facts based on Ω_0. The fact f is actually a set of facts with credence attached to each of them: $\Omega_0 \times y_i = \{C_1 w_1, C_2 w_2, \ldots, C_\ell w_\ell\} \times y_i \rightarrow \{C_1 f_1, C_2 f_2, \ldots, C_\ell f_\ell\}$. Of course, it is possible for all the facts $(f_1, f_2, \ldots, f_\ell)$ to be the same, in which case the DM has no uncertainty with respect to the meaning of the datum y_i. Upon receipt of a datum $y_j \not\varepsilon Y$, the DM decodes the symbol into information, $\Omega_0 \times y_j \rightarrow \hat{f}$, then checks the triple $(y_j, \Omega_0, \hat{f})$ for reasonableness with respect to his personal meaning system. This filtering process may indicate the credence vector needs to be revised in order to accommodate the new datum and the interpreation of it. Recall that the world view sets the criteria for a formulated problem specification. The change in the world view, Ω_0 to Ω_1, is equivalent to the change in one or more criteria for a formulated problem. The change could have the effect of reducing uncertainty as to the proper view (conflict resolution)

or it could actually increase uncertainty (conflict generation) and induce the DM to seek additional information in order to reduce his internal conflict. The effect of changes at the world view level can result in different specifications of the act space and the utility assessment, as well as the components that were subject to uncertainty, at the formulated problem level. One should note that the change in world view dictates a fundamental change in the formulated problem, and the comparison of utility measures under two different world views is invalid, analogous to the inter-personal utility comparison. The value of information for world view level changes cannot be evaluated based on the utility measures of the given formulated problem. Therefore, we are suggesting the magnitude of the changes (conflict reduction or generation) as a measure of the value of information in the meta-decision theory framework. We formalize the above discussion in the next subsection.

B. Value of Information in Meta Theory

Consider a DM with initial world views and past Data Y.

$$\Omega_0 = \{C_1 w_1, C_2 w_2, \ldots, C_\ell w_\ell\}$$

Then the AC problem specification is based on the Ω_0:

$$\Omega_0 \times Y \rightarrow \{A_0, S_0, Z_0, U_0, \Phi_0\} = \delta_0$$

The formulated problem δ_0 may be consistent with all the views in Ω_0; $w_i \times Y \rightarrow \delta_0$ for all views $w_i \varepsilon \Omega_0$. More likely, some views are consistent with δ_0 while others are not. Then the δ_0 can be stated as the AC problem with the greatest credence attached to it:

$$C_{\delta *} = \underset{\delta \varepsilon \Delta}{\text{Max}}\, C_{\delta j} = \underset{\delta \varepsilon \Delta}{\text{Max}} \sum_{w} c_i g(w_i, \delta_j) \qquad (9)$$

where $g(w_i,\delta_j) = \begin{cases} 1 & \text{, if } w_i \times Y \rightarrow \delta_j \\ 0 & \text{, otherwise.} \end{cases}$

The credence attached to the formulated problem δ^* is C_{δ^*} and the measure $(1-C_{\delta^*})$ represents the magnitude of a DM's internal conflict as to the correct specification of the formulated problem. Mitroff [18] refers to the measure of conflict $\gamma = (1-C_{\delta^*})$ as the probability of an error of the third kind: the error of formulating the wrong problem. The conflict reducing role of information is to increase the credence attached to the formulated problem. Thus, the maximum amount of conflict reduction that can be expected given the current state of the DM's world-view is $(1-C_{\delta^*})$. This measure is analogous to the expected value of perfect information $(V(\eta_p))$ at the formulated problem level. That is, if a given information system can reveal the "true environment" for the formulated problem, the DM can adjust the credence vectors such that all the component specifications are consistent with each of the remaining views.[22] Thus, the conflict reducing value of information system η is:

$$
\begin{aligned}
I(\eta) &= E[C_{\delta^*_1}] - C_{\delta^*_0} \\
&= E[\underset{\delta\varepsilon\Delta}{\mathrm{Max}}(C_{\delta_j}|\eta)] - \underset{\delta\varepsilon\Delta}{\mathrm{Max}}\, C_{\delta_i} \\
&= E[\underset{\delta\varepsilon\Delta}{\mathrm{Max}} \sum_{w}(C_i|\eta)g(w_i,\delta_j|\eta)] - \underset{\delta\varepsilon\Delta}{\mathrm{Max}} \sum_{w} C_i g(w_i,\delta_j) \qquad (10)
\end{aligned}
$$

where δ^*_i is the formulated problem at time period i.

One should note that the value of information in (10) above does not possess the same properties of the value of information at the formulated

problem level as defined in equation (7). The conflict reducing value (10) applies to the task of formulating the correct problem while the traditional value (7) applies to the task of choosing an optimal act given a formulated problem. Therefore, the two value measures cannot be summed together to yield the total value of information.

Now, let us consider the conflict generating role of information. Hegel argues that synthesis (the meaning system level) does not exist without prior conflict--ideas are generated out of opposition [3, pp. 170-179]. Therefore, the generation and/or recognition of conflict is a necessary condition for a person to learn. Earlier we assumed a datum could increase the credence (and decrease the conflict) attached to a formulated problem. But a new datum can decrease the credence (and increase the conflict) as well. That is, $C_{w_1^*} < C_{w_0^*}$, which implies that the DM is less convinced that the formulated problem is correct than he was before the receipt of the datum, thus increasing the subjective probability of the error of the third kind by $C_{w_0^*} - C_{w_1^*}$. Consequently, the amount of conflict reduction that can be received has increased to $(1-C_{w_1^*})$. The DM now has been motivated to search for conflict reducing information. Note that the state of the DM's world views which maximizes the conflict is where every formulated problem is equally credible:

$$C_{\delta_i} = C_{\delta_j} \text{ for every } \delta\varepsilon\Delta.$$

Then the maximum expected conflict increasing value of information can be stated as: $C_{w_0^*} - \frac{1}{k}$ where k is the number of $\delta\varepsilon\Delta$. The motivation role of information is to increase conflict such that the DM would be motivated to generate new ideas at the meaning system level while trying

to resolve the conflict.[23] While the mechanics of generating the measures of conflict reducing and conflict increasing values of information are the same, the two measures which only differ in sign, are fundamentally different. While the first reduces internal conflicts for the DM, the second provides the opportunity for additional conflict reduction in the future.

While we were able to identify the measures and some properties of information in meta-theory, we were not able to define the means to systematically revise the credence measures based on information received. Note that the formulated problem is conditional upon the DM's world-views being constant, and capable of being explicitly stated. Likewise, the explicit specification of world view changes requires that our meaning system be static, at least during the analysis, and be susceptible to explicit specification, which we are not able to do under our current state of knowledge. Thus, the means to include the conflict increasing and decreasing role of information in an information system are mainly conjectural and speculative (see Mitroff and Betz [19] and Mason [15] for examples.)

In short, within the framework of SDT, the role of information is defined as uncertainty reduction. In the framework of meta theory, the role of information is not only in reducing conflict, but also in increasing conflict. However, the explicit treatment of the world view revision, and thus the impact of information, is not feasible under our current state of knowledge.

In the next section we provide a simple example to illustrate the various concepts discussed here.

V. An Example of Information at the World View Level

A simple cost-volume-profit situation using a standard costing system will illustrate the implications of a meta theory for information value. The decision maker is the general manager of a manufacturing firm. Below are some relevant assumptions for the setting.[24]

(1) objective: maximize profit

(2) major departments: manufacturing and marketing

(3) sales price: \$51 per unit

(4) product cost (standard):

(a) $(TC|w_1) = 160 + 47Q$ (world view 1)

(b) $(TC|w_2) = 800 + 31Q + .1Q^2$ (world view 2).[25]

(5) based on the past data and the DM's educational background, the DM attaches the credence measures of (.9,.1) to the world views w_1 and w_2 respectively: $\Omega_0 = (.9w_1, .1w_2)$.

(6) the current period sales is 110 units at \$51 per unit.

(7) the actual production cost for the 110 units is \$5,380.

Tables 1 and 2 and Figure 2 summarizes the above assumptions. Also, note that the two views (w_1 and w_2) did not conflict with each other with respect to the interpretation of the past data (Figure 2), since the standards based on the two views were quite similar. The report of current period activities, however, raises a problem for the DM.

Table 1: Basic Cost Standards

	Standard Cost	Break-even Quantity	Optimal Quantity	Credence Level
w_1	$160+47Q$	40	Unbounded	.9
w_2	$800+31Q+.1Q^2$	51;149	100(π=\$200)	.1

Table 2: Actual vs. Standards

	w_1	Actual	w_2
Sales	\$5,610	\$5,610	\$5,610
Cost	5,330	5,380	5,420
Profit	\$ 280	\$ 230	\$ 190
Cost Variance	50U		40F

Taking the actual performance data as depicted in Figure 2, let us try to infer the "facts" that result from conjoining the actual data to each of the alternative world views, separately.

Linear World: w_1	Quadratic World: w_2
(1) The efficiency of the manufacturing department is questionable. Investigate, not-investigate decision should be made.	(1) The manufacturing department was quite efficient. No need to make investigate, not-investigate decision.
(2) The worse than expected profit realized during the period was due to the manufacturing department's inefficiency.	(2) The better than expected profit was due to the manufacturing department's efficiency.
(3) Increased sales and more effective cost control is the means to increase profit in the next period.	(3) Reduced sales, to 100 units, is the means to maximize profit in the next period.
(4) The decision to continue producing this product is dependent upon market demand projections compared to other opportunities.	(4) The decision to continue producing this product is mainly dependent upon the adequacy of the maximum expected profit of $200 compared to other opportunities

Note that the "facts" inferred from the cost accounting report are radically different, depending on which view the DM adopts. It is irrelevant which view is the correct one, in fact both of them could be incorrect. The accounting report could lead to an increased internal conflict in the DM's mind. While we cannot determine exactly how the credence levels would be revised after the receipt of the accounting report, it is likely that the credibilities attached to the views would change, C_i vs. $(C_i|y,n)$.[26]

Recall that the manager's probability of an error of the third kind (γ) was zero in the past, since both views-of-the-world yielded the same standard cost criteria. The expected measure of γ for future periods was .1, since the linear world view (w_1) had a credence of .9 under Ω_0. The ex-post measure of γ, $(\gamma|y,n,\Omega_0)$ is $1 - \underset{w}{\text{Max}}\ P(w_i|y,n)$,

which may be different from .1: $E(\gamma|\Omega_0) \gtreqless (\gamma|y,\eta,\Omega_0) = (\gamma|\Omega_1)$.
If the ex-post measure $(\gamma|\Omega_1)$ were smaller than the ex-ante measure $(\gamma|\Omega_0)$, the accounting report had a conflict reducing effect, and if the ex-post measure were larger than the ex-ante measure, the information had a conflict generating effect. Should the conflict increase, the DM is likely to seek additional information to reduce the conflict. It is argued that the accounting systems designer should explicitly consider the impact of information at the world view level in addition to the value of information at the formulated problem level.

Summary

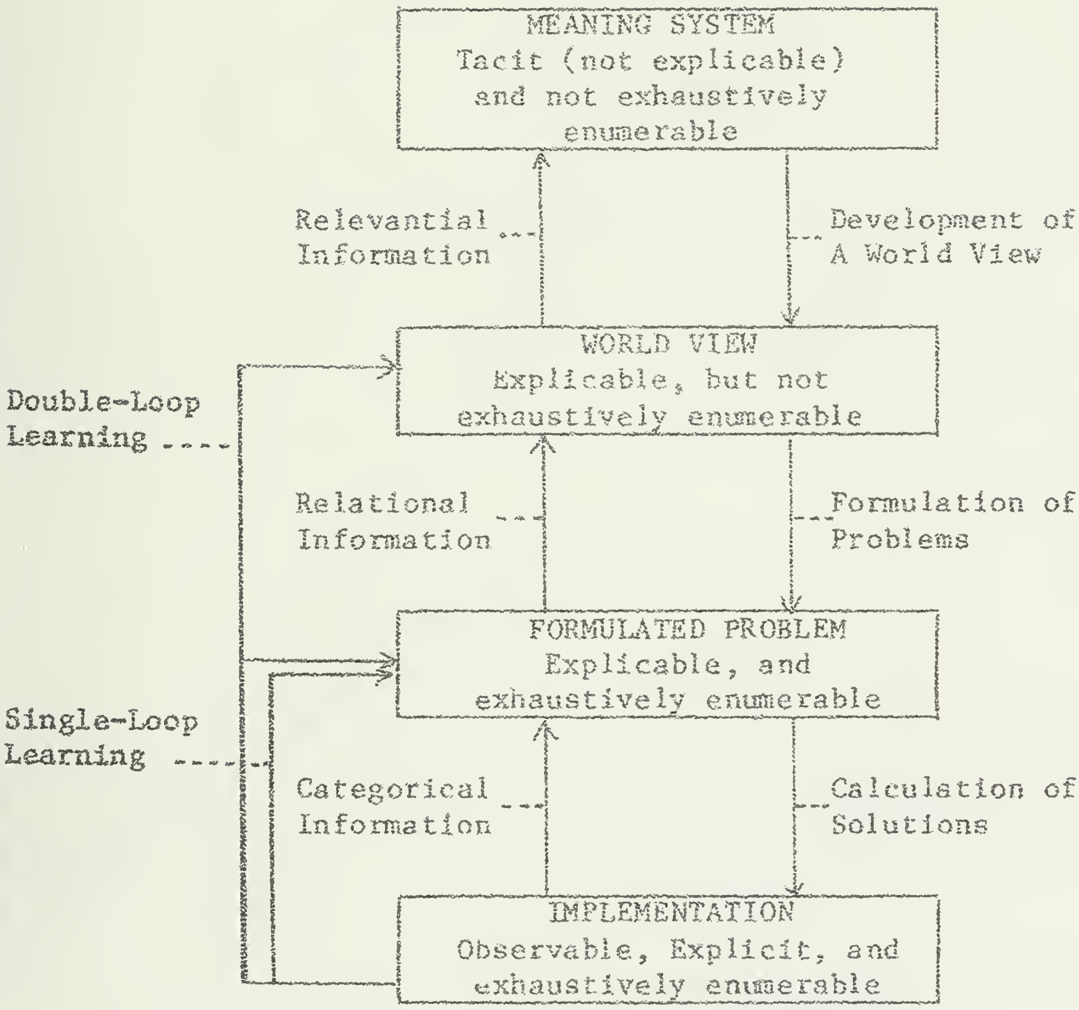
We have introduced a multilevel model for the evaluation of information systems, and focused our discussion on the value of information at two of those levels--the formulated problem level and the world view level. The analysis has pointed out that the impact of information at each level is fundamentally different.

At the formulated problem level, information has value to the extent that it reduces uncertainty under a standard SDT framework. While our analysis has attempted to point out some technical problems in the probability revision process for act dependent and uncertain outcome formulations, the uncertainty reduction value of information remains valid.

At the world view level, however, the impact of information may be conflict increasing or conflict decreasing for the individual. While the same datum may have both information impacts, the uncertainty and conflict changes are not additive, and there is no continuity of

uncertainty between two formulated problems for the same individual. Each formulated problem results from the perplexity or conflict of a different set of world views.

The value of information is multifaceted, and a multifaceted evaluation technique is required. An inquiry system perspective, which relates the variety of the multilevel process presented here to the variety required by the implementation situation, is one direction that future research might pursue. This would suggest research on the classes of problems which must be inquired about through the use of an information system, and the inquirying capabilities of alternative information system designs, with the user of the system as an integral part of the inquiring capability assessment.



MEANING SYSTEM
Tacit (not explicable) and not exhaustively enumerable
Relevantial Information
Development of A World View
WORLD VIEW
Explicable, but not exhaustively enumerable
Double-Loop Learning
Relational Information
Formulation of Problems
FORMULATED PROBLEM
Explicable, and exhaustively enumerable
Single-Loop Learning
Categorical Information
Calculation of Solutions
IMPLEMENTATION
Observable, Explicit, and exhaustively enumerable

Figure 1

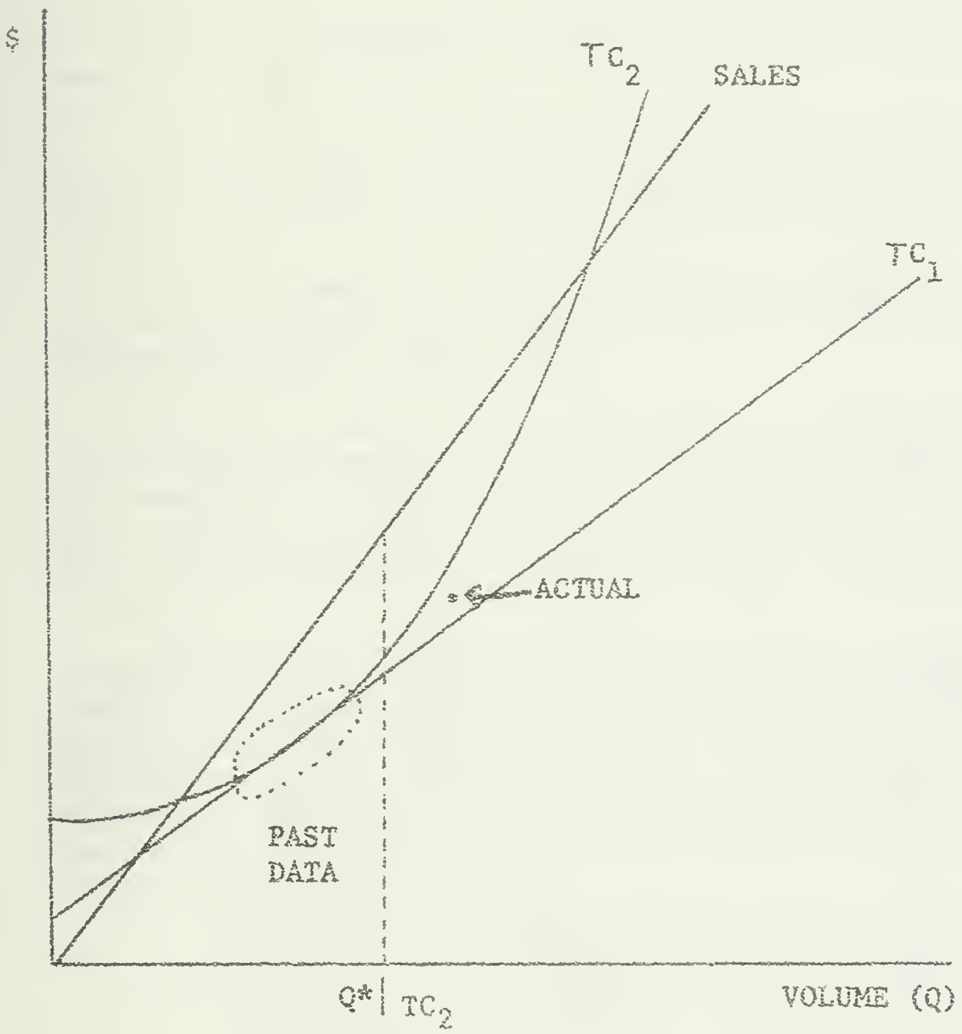


Figure 2

Footnotes

[1]This is essentially Anthony's description of strategic and managerial planning [1].

[2]Here we are using Simon's [31] distinctions between Intelligence (identifying the need to make a decision), Design (developing alternative courses of action) and Choice (selection of an alternative).

[3]This framework is in addition to the resource allocation problem typically employed and is based on Katz and Kahn's The Social Psychology of Organizations, Wiley, 1966.

[4]Cyert and March's limited search, localized rationally and sequentially attention to goals and March and Simon's bounded rationality are examples of this process of gaining "closure" by artificially limiting the problem space [4,12]. Lawler and Rhode [11] also stress the need to meet an "expectation" of rationality in an organization context.

[5]There are a number of analogous multi-level models to represent the process of active sense making. For instance, Watzlawick, Beavin and Jackson [37] use a metacommunicative framework, Osgood [23] uses an encoding-decoding framework, Mead [16] uses a symbolic interaction framework, Torbert [35] uses a level of consciousness framework and Messarovic [17] uses a cybernetic control framework. Perhaps the best source for justifying a multi-level hierarchical model of the information system user is William James:

> Looking back, then, over this review, we see that the mind is at every stage a theatre of simultaneous possibilities. Consciousness consists in the comparison of these with each other, the selection of some, and the suppression of the rest by the reinforcing and inhibiting agency of attention. The highest and most elaborate mental products are filtered from the data chosen by the faculty next beneath, out of the mass offered by the faculty below that, which mass in turn was sifted from a still larger amount of yet simpler material, and so on. The mind, in short, works on the data it receives very much as a sculptor works as on his block of stone. In a sense the statue stood there from eternity. But there were a thousand different ones beside it, and the sculptor alone is to thank for having extricated this one from the rest. [The Principles of Psychology (1890) Dover, 1950, pp. 289-290.]

[6]While there is no general agreement on this point, Sperber [32] argues that symbolism is a cognitive "...mechanism that alongside the perceptual and conceptual mechanisms, participates in the construction of knowledge and in the functioning of memory." [32, p. xii] He contrasts symbolic knowledge with semantic knowledge in that the later is

of categories and classifications while the former is about the world itself. While it is possible to have an exhaustive, "encyclopedic", knowledge of the meaning of a word, it is not possible to have an exhaustive knowledge of that which the word represents. Such knowledge involves symbolism of which, "...there is a potentially indefinite number of new metaphors, dream-like associations..." [p. 93], and with each new metaphor, "...symbolic knowledge is able to take on new knowledge and similarly enrich itself." [p. 93] Each enumerated symbolic interpretation suggests new as yet unsuspected potential interpretations, which themselves suggest..., etc., etc.

[7]Polanyi argues that "all thought contains components of which we are subsidiarily aware in the focal content of our thinking...in an act of tacit knowing we attend from something for attending to something else; namely from the first term to the second term of the tacit relation." [26, p. x] The subsidiary awareness from which we attend to focal awareness remains tacit, personal, and beyond explicit analysis, yet is the basis for knowing our focal awareness to be true. Thus "One can know more than one can tell." [26, p. 7]

[8]Space limits the discussion of the full implications of a hierarchical theory. Interested readers are directed to [24] or [17].

[9]Demski [6], and Feltham and Demski [9] labeled the set Ω the "level of experience".

[10]An expected utility maximizing DM who spends resources to obtain information is assumed in this paper. Other criteria, such as min-max and max-min, can be analyzed within the above structure by supressing certain components.

[11]Although the standard SDT framework assumes act-independent states of nature [28,27], our formulation allows for act-dependent states of nature since some writers in accounting [8,9] have partially dealt with the act-dependent states. Later notes identify where our analysis extends beyond others.

[12]Another useful concept of the value of information is called the conditional value of information [27, § 4.5.1] and is defined as

$$V'(\eta) = EU(a^*|\eta) - EU'(a_k) \qquad (4)'$$

$$EU'(a_k) = \sum_y [\sum_s U(z_{kj})\phi(s_j|a_k, y_\ell, \eta)]\phi(y_\ell|\eta)$$

where a_k is the optimal act based on the AC problem specification before the employment of the information system η:

$$EU(a_k) = \max_{a \in A} \sum_s U(z_{ij})\phi(s_j|a_i) \text{ for all } a \in A.$$

The major difference between (4) and (4)' is that equation (4) compares the ex-ante, ex-post (before the decision, after the information) measure against the ex-ante, ex-ante measure, while equation (4)' compares the ex-ante, ex-post measure to the ex-ante, ex-post measure. Ex-ante (befor the information) values of $EU(a^*)$ and $EU'(a_k)$ are equal. While the expected values of the equations are the same, the formulation (4)' insures the value of "surprise" information to be non-negative. However, since we cannot assess the value of $V'(\eta)$ before the adoption of a given information system, equation (4) will be used for information systems choice decisions.

[13]Under an act dependent state occurrence framework, as presented in this paper, the state predicted by a signal may not be unique. That is, it is possible to have

$$\phi(s_i|a_i, y_\ell, \eta_p) = 1 \quad \underline{\text{and}}$$

$$\phi(s_j|a_j, y_\ell, \eta_p) = 1, \text{ yet}$$

$$s_i \neq s_j \ .$$

In this case the act state pair that determines the outcome z_* is the pair (a_ℓ, s_ℓ) such that

$$\underset{(a,s)\varepsilon(A,S)}{\text{Max}} \quad U(z_{ij})\phi(s_j|a_i, y_\ell, \eta_p).$$

[14]See Feltham and Demski [9, p. 625] for more expanded illustration.

[15]Feltham and Demski [9] treated the probability measures $\phi(\overline{s})$ to be independent of the past acts. It is difficult to rationalize the act independence assumption for past events when the model calls for act dependence for future events $\phi(s|a)$.

[16]Feltham and Demski's formulation [9, p. 625] did not address the action-effectiveness component, and Mock [1971] labeled it the "Action Effectiveness Value of Information," but did not incorporate it into the decision model.

[17]Mock [22] called the increase in the expected utility due to the revised outcome probabilities, the "Model Value of Information," but again he did not incorporate it into the decision model.

[18]To do so we would commit an error of logical types as developed by Bertrand Russel. We would be trying to reconcile two statements—one (s) a statement of a formulated problem, the other (s') a statement about that statement. To discuss the language of (s) a meta language is necessary. We realize this is a problem without bounds—"There is no ultimate meta language which can comment on the system of relationships, because the mean of analysis—meta language—like the observer, is also

part of the system being analyzed." [38, p. 94] Our purpose is not to resolve the problem of meta languages, but to discuss its implications for evaluating information systems, as the relationship of the world view level to the formulated problem level.

[19] Very briefly, Lockean inquiry systems (IS) rely on consensus of empirical data in the absence of theory, Liebnizian IS rely on formal theory in the absence of data, Kantian IS rely on multiple theories (as world views) interpreting common data, and Hegelian IS rely on conflicting "deadly enemy" theories debating thesis and antithesis using common data. Churchman-Singerian IS employ all modes plus implementation. Mitroff and Pondy give a good overview of each [21].

[20] Adapted from Churchman [3].

[21] A special case of this formulation is the certainty case (i.e., $c_j = 1$ and $c_i = 0$ for $i \neq j$).

[22] Complete faith in one view, $c_i = 1$, is sufficient but not necessary to achieve the state of $C_{\delta*} = 1$.

[23] Mock [22] has recognized this role of information and has suggested the following hypothesis:

> <u>Anti-Learning Information System-Designs</u>: Information systems should be designed such that "learned" views-of-the-world and their underlying assumptions are continuously challenged.

It is interesting to note that Mock, using an uncertainty reduction framework for the value of information, and attending to the formulated problem level, refers to this essential aspect of the inquiring process as <u>anti-</u>learning.

[24] The problem was adapted from a problem suggested by Professors Green and Dopuch.

[25] It is a trivial exercise to generate a set of data such that the residual sum of squares for the two models are identical. Therefore, the two cost functions can be assumed to have been estimated based on the same past data.

[26] If we assume that the standards $(TC|W_1, TC|W_2)$ are not considered to be certain, rather the costs are distributed according to some known distribution, then we can consider a plausible revision process. Assume that:

$$(TC|w_1) \sim N(160+47Q, \sigma^2)$$

$$(TC|w_2) \sim N(800+31Q+.1Q^2, \sigma^2)$$

Then, the credence measures can be revised based on the likelihood measures of incurring the actual cost given the standard cost equations, $P(y|w_i)$.

$$P(y|w_1) = P(5380|C = 160+47Q, A=110, \Omega_0)$$

$$P(y|w_2) = P(5380|C = 800+31Q+.1Q^2, Q=110, \Omega_0)$$

$$P(w_i|y,n) = f\left[\frac{P(y|w_i)P(w_i)}{\sum_w P(y|w_i)P(w_i)}, \Omega_0, y, n\right]$$

It is not certain that the credence levels would be revised according to Bayes' rule, since the product of the revision process must be filtered through the meaning system level.

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